Chair of Energy Systems
TUM School of Engineering and Design
Technical University of Munich

District Energy System Optimization with Detailed Modelling of the Heating Sector

Lennart Trentmann[1], Amedeo Ceruti[1], Benedikt Schweiger[1], Hartmut Spliethoff[1]

[1] Technical University of Munich, Chair of Energy Systems, Germany

Introduction

The building sector plays a crucial role in achieving greenhouse reduction targets, partly because of the current low share of renewables in the energy mix. In 2022, only 17.4% of the heating delivered in Germany came from renewable sources [1]. A comprehensive transformation of the energy supply is required to achieve the greenhouse gas reduction targets. Especially because of the increasing coupling of the electricity, heating, cooling, and mobility sectors and the volatility of renewable energy supply, conventional energy system planning methods used in practice are reaching their limits. Mixed-integer linear programming and optimization are valuable tools to design and plan our future energy system.

Renewable Energies Time Series Calculation

Time series for various renewable technologies are created based on satellite weather data. The structure for determining site-specific generation time series is shown schematically in Figure 2. For example, atlite is used to produce yield time series for wind and PV. Hourly variable COPs can be calculated with oemof.thermal for decentralised systems and for large-scale heat pumps with Jesper et al.'s semi-empirical models.

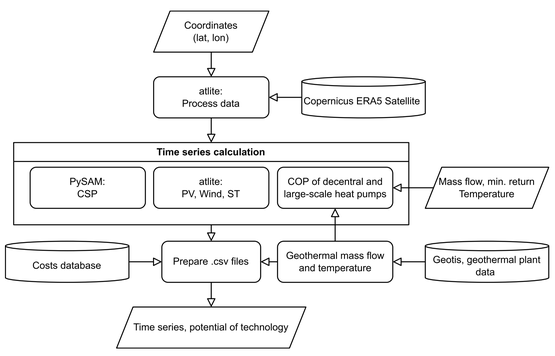

Figure 2. Schematic representation of the time series calculation of the renewable energy sources

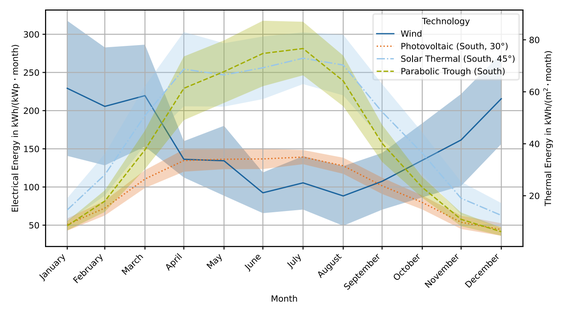

Figure 3. The average monthly yield of renew-able energies at the Garching site (2000 – 2021)

Heat Demand Calculation

Heat, power and cold demand are estimated using Level of Detail 2 (LoD2) Geographical Information System (GIS) data pre-processed using FME software [2]. Each building is assigned an age category based on the age distribution information provided by the Zensus2011 dataset [3]. In addition, a building type is assigned to each building. The obtained data, together with the local weather data, are used to calculate the heating and electricity demand using City Energy Analyst (CEA) [4] or demandlib [5].

Methodology for Detailed Modelling of the Heat Sector

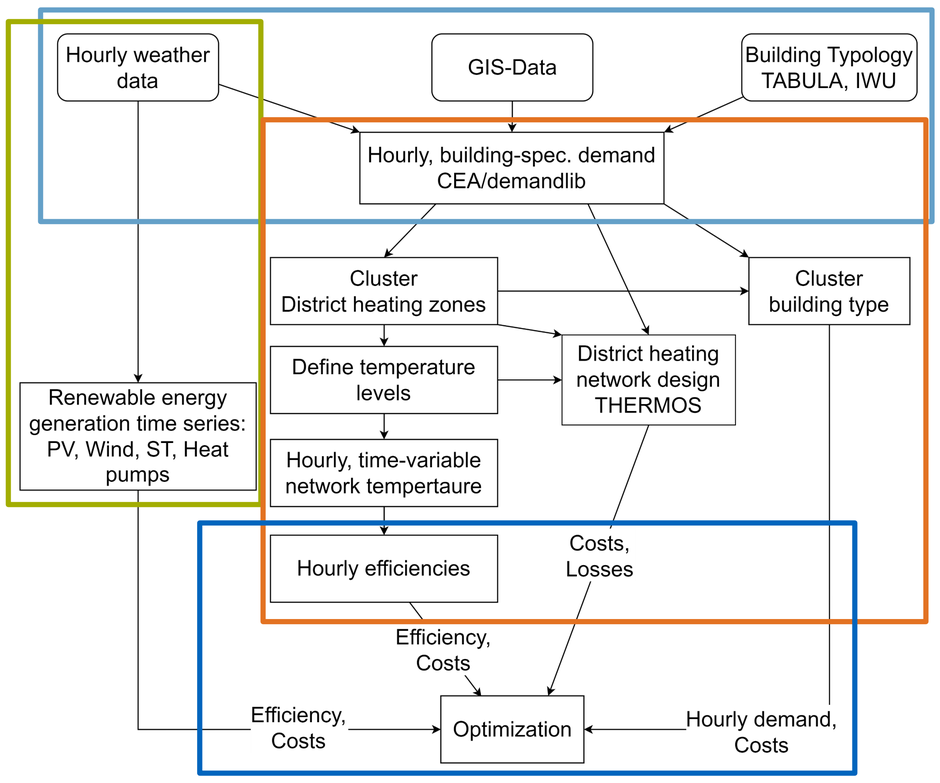

Figure 1. Overview of the preprocessing methodology to determine time series, potential and costs of an area

Clustering of District Heating Zones

The decision between building-specific and district heating network-based heat supply is crucial for transforming heat supply systems. District heating network design cannot be integrated into holistic optimization and must be done separately, requiring spatial subdivision. To achieve this, GIS data is graphically prepared for the initial area division of possible connected district heating network areas, corresponding to motorways, federal highways, railway lines, contour lines, and so on (see figure 4).

Figure 4. Example of Clustering of District Heating Zones

District Heating Network

Based on the identified peak loads, the district heating network is designed. The resulting costs and losses of centralized district heating supply are input parameters for the district energy system optimization. Tools such as topotherm [6] or THERMOS [7] are used for this purpose.

Figure 5. Example of District Heating Network Design

Optimization

To represent the technological structure of energy systems in the optimization model, each district heating network and their expansion stage is represented by a district heating node. This node includes various conversion and provisioning processes, as well as transfer capabilities between the networks. The model takes into account different heat supply technologies and temperature levels in the network, latter are implemented via binary decision variables. Building-specific heat supply is modeled by building clusters and different technologies.

Conclusion and Outlook

The optimization-based planning approach allows for the consideration of the fluctuating characteristics of renewable energy sources and weather dependent demand. Furthermore, it enables the interplay between sectors to be taken into account.

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Lennart Trentmann, M. Sc.
Lennart.trentmann@tum.de
+ 49 89 289 16287

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